Results from a Paired Sampling Regime

❖ **Runner Up** ❖
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Abstract
In Puget Sound, the supralittoral zone—the area above mean higher high water (MHHW) influenced by splash and extreme high tides—produces intertidal and terrestrial invertebrates that are prey for outmigrating juvenile ocean-type salmonids. However, extensive shoreline armoring may have negatively affected production in this zone by truncating or eliminating upper beach and riparian habitat. This study compared adjacent altered and natural beach stretches at four sites in central Puget Sound. To assess invertebrate assemblages in the supralittoral zone, two sampling schemes were employed: insect fall-out traps captured terrestrial and shore insects originating from backshore vegetation and beach wrack; and sediment cores were taken to collect invertebrates (e.g. gammarid amphipods, annelid worms, insect larvae) associated with sediments and deposited wrack. Natural beaches had higher abundances and greater taxa richness in both fall-out traps and benthic cores than did armored beaches. Because juvenile salmon captured in the nearshore often have high proportions of beach and terrestrial insects, these data underscore the importance of maintaining more natural beaches and shoreline vegetation, and suggest that habitat restoration to recreate natural beach processes is important in recovering important lost biological function of Puget Sound beaches.

The purpose of this study is twofold: (1) to assess the biological role of the supratidal zone, specifically with respect to potential salmonid prey resource occurrence and abundance and (2) to evaluate how the biological structure and function changes when the shoreline is armored. By quantifying invertebrates at both altered and natural beach stretches, this project aims to measure and describe the effects of shoreline armoring on upper intertidal and supratidal biota (Sobocinski 2003).

The supratidal zone (also referred to as supralittoral) is a unique ecotone, the ecology of which has been little studied. Because it is the most terrestrial portion of the intertidal zone, it often has escaped notice of marine ecologists and terrestrial specialists. However, it is the nexus between the two systems and possesses characteristic properties of both; it is a dynamic zone which is of great importance in energy exchange and nutrient flux in the greater nearshore ecosystem (Polis 1996; Zimmer et al. 2002). The supratidal zone is defined as the area above mean higher high water (MHHW), influenced by splash and extreme high tides, generally 3.2 m (10.5 ft) and higher (above MLLW) in central Puget Sound (Carefoot 1977). The ecology of this zone is driven by both terrestrial and marine processes including: marine wrack deposition, terrestrial leaf litter input, sediment deposition from bluff erosion, and deposition of large woody debris. Large woody debris deposition can be either an aquatic or terrestrial process, depending on whether the debris is deposited from the water by longshore currents or in-put directly from the upland. Additionally, physical factors specifically associated with tidal marine systems, such as exposure, fetch, tidal current and height, drift cell dynamics, and sediment grain size are likely to be important drivers.

Research has shown that changes in physical structure and function, including coarsening of sediments, deflection of wave energy, and increasing erosion downshore (Canning 1995; Inman 1973; Macdonald 1994; Nordstrom 1989). Modifications, specifically bulkhead armoring, produce many physical alterations: the removal of backslope vegetation and large woody debris, introduction of new material (often dissimilar to the natural substrate) and the replacement of beach with hard and/or vertical surfaces. Consequently, these structures have the potential to eliminate or significantly modify the natural supratidal zone, especially when modifications are installed at or below MHHW.

In order to study impacts of structures on invertebrate assemblages, four sites with adjacent stretches of altered and natural beaches were selected for a paired sampling regime. The sites were: Seahurst Beach in Burien, WA; Richmond Beach in Shoreline, WA, Carkeek Park, in Seattle, WA, and Dockton Beach, in Quartermaster Harbor, between Vashon and Maury Islands, WA. Paired sites were selected for this study because of the minimal effects of differing oceanic regimes associated with close spatial proximity. It is important to note that sediment and benthic infauna samples were taken at lower elevations at sites with shoreline armoring, since structures precluded the collection of samples in the supratidal zone. A synoptic sampling regime, whereby all samples were taken at an even elevation at both altered and natural sites, was conducted to account for this variation, however results were not presented for this conference. Methods derived from the Estuarine Habitat Assessment Protocol (Simenstad 1991) were used to collect data on organic detritus percent cover, benthic infauna, sediment grain-size, and insect assemblages

Natural beach sites had more deposited wrack, large woody debris and leaf litter. Wrack is an important component of the supratidal zone, in that it serves as a food source and habitat for intertidal biota, including talitrid amphipods and several species of Diptera (flies).

Sediments were generally coarser at altered beach sites. Natural beach sites were predominantly composed of medium-grained mixed sand, while altered beach stretches were dominated by gravel, suggesting that shoreline armoring coarsens sediments.

Benthic infauna at both natural and altered sites generally had low taxa richness and patchy organism distribution. Therefore, taxa were put into the following functional groups for analysis: Oligochaeta, Nematoda, Insecta (includes all adult and immature insects), Talitridae (includes two genera and immature talitrid amphipods), Crustacea (includes all marine organisms, such as Ostracoda and Copepoda), Collembola, and Arthropoda (which includes Acari and Arachnida). Oligochaete and nematode infaunal worms were numerically dominant in all samples. All other taxa, with the exception of Crustacea, showed significantly higher abundances at natural beach stretches; crustacea were significantly more abundant at altered beach stretches. All results were determined using ANOVA, $\alpha=0.05$.

Benthic infauna data also were analyzed using nonmetric multidimensional scaling, a multivariate technique. This procedure resulted in three distinct groupings of samples: one group showing natural stretches from three sites, one showing altered samples from the same three sites, and one cluster showing both natural and altered samples from Dockton Beach, which is located in a low energy system compared to the others. Indicator species analysis demonstrated that talitrid amphipod presence and abundance were driving the multivariate model.

The insect assemblage among the sites was highly diverse, including over 100 taxa, but individual samples were marked by numerous rare species and many zero counts. Taxa richness was higher at natural beach sites, perhaps due to the presence of intact vegetation. Dominant taxa included: Chironomidae, other Diptera, Talitridae, Homoptera, Coleoptera, and Collembola. Diptera, including Chironomidae were ubiquitous, though occurred in significantly higher abundances on natural beach stretches. Homoptera (including cicadellids and aphids) were tightly associated with vegetation and were found in significantly higher numbers at natural beaches at two of the four sites. As in the benthic infauna, Talitridae were more abundant at natural beach stretches.

Because the supratidal zone is neither entirely terrestrial nor marine, it is truly an ecotone and possesses many attributes of an ecological edge (Carefoot 1977; Simenstad 1997). Both infauna and insect fallout samples collected terrestrial and marine organisms. Benthic cores, by nature, were more apt to collect taxa adapted to living in the supratidal zone such as infaunal worms and talitrid amphipods, which were often in their burrows during daytime sampling. Insect fallout traps collected some localized taxa, such as amphipods, oniscoid isopods, and staphylinid beetles, however it is likely that most of the flying insects captured were imported from surrounding vegetation. Since many of these insects are tightly associated with vegetation, and vegetated sites in this study show greater diversity and abundance, emphasis should be placed on maintaining shoreline vegetation.

Shoreline armoring has negative impacts on the invertebrate assemblage in the supratidal zone. This study begins to draw linkages between the terrestrial and marine system via this zone, however many trophic relationships are still unknown. Identifying and quantifying these associations is the next step in analyzing the contribution the supratidal zone is making to the Puget Sound nearshore ecosystem.

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